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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

Electronic Warfare Module of the Simulation of Tactical Alternative Responses(STAR) Module

by

Stephen Lamar Maddox
and
Ambrose Robert Hock

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Electronic Warfare Module of the Simulation of Tactical Alternative Responses(STAR) Module

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ABSTRACT

This thesis represents an analysis of the effects of Electronic Warfare(EW) on the outcome of a battle from the high resolution combat simulation model STAR (Simulated Tactical Alternative Responses). The analysis was performed on data generated by the STAR model. An overview of the STAR model and an explanation of the EW model used is included to provide a good background with which to understand the analysis performed. Conclusions resulting from the analysis and enhancements to the EW model are presented along with recommendations for future analysis of the EW model.

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I. INTRODUCTION

The area of combat modelling has evolved over the years from simple board games to highly sophisticated combat simulation models. The awareness of the complexity of the combat process in developing a combat simulation model is very important. Early model developers concentrated their efforts on homogeneous, force on force engagements, however, the need to understand the effects of different force sizes, terrain changes, doctrine, and the increased technological advances in weaponry and electronics, forced model developers to expand the scope of the models being developed.

Because of a lack of operational data, effectiveness of weapons systems has often been estimated for use in combat simulations. Often military planners rely upon these simulations to provide guidelines for the decision process. However, at the same time, military planners must be careful not to utilize these simulations to predict the precise outcome of a particular battle.

As combat modelling has evolved, various modelling techniques have been utilized to simulate the

characteristics of the combat process. Also, analysis has been performed on the results generated by these models. This analysis has resulted in improved models that more realistically simulate the combat process. The Simulation of Tactical Alternative Responses (STAR) Model is an example of the evolved combat simulation model. Over the years, STAR has been developed through the efforts of many graduate students and faculty at the Naval Postgraduate School. Until recently, however, one important aspect of combat warfare, namely Electronic Warfare (EW), had not been incorporated into the complete version of the STAR model. STAR, like many combat simulation models, regarded communications as a guaranteed process and therefore ignored the concept of electronic warfare. The military planner can not afford to neglect the impact of impaired communications on the battlefield. United States forces rely almost entirely upon some type of radio communications for command and control during battle and therfore must protect communications links against electronic warfare measures and learn to operate in an active EW environment. Threat forces concentrate on training and research into the active use of EW. The use of chaff during the 1968 invasion of

Czechoslovakia to confuse European radar operators, and the various EW measures used in the Arab-Israeli War of 1973 demonstrate the intentions of the Soviet forces to actively use EW on the modern battlefield.

At the present time, a model of electronic warfare has been developed for incorporation into the complete version of the STAR Model. The purpose of this thesis was to analyze the EW module and its interaction with the STAR model to determine EW's effect on the outcome of the simulation. Several experiments were designed to help in the analysis and will be discussed in Chapter V, VI, VII, and VIII. Experiments involving position changes of the EW elements, and varying the EW tactics employed were performed to generate data for the analysis. The intent of this study was to better understand EW effects in combat and the impact of the addition of EW to a high resolution combat simulation model, as well as to validate and suggest enhancements to the current operating electronic warfare module.

II. OVERVIEW OF THE SIMULATION OF TACTICAL ALTERNATIVE RESPONSES MODEL

The Simulation of Tactical Alternative Responses (STAR) Model is a high resolution, next event simulation of a combined arms battle between Blue and Red forces at Brigade level and lower on a conventional battlefield. The model is currently under development at the Naval Postgraduate School. The STAR model was developed to provide an event simulation model to aid in evaluating weapons and tactics. The model is written in the Simscript computer language, level II.5, to take advantage of the powerful statistical and simulation tools this language can provide. Simscript is designed for use in the simulation of discrete events and its free form syntax makes programs easily understandable by the user. Internal to the Simscript language is an entity-attribute structure whereby a single entity can be described using numerous attributes that are designed to describe that entity throughout the simulation. This provides for easy access of these attributes during the simulation.

The STAR model contains many subdivisions ("modules") that are a result of the combined efforts of the faculty and students at the Naval Postgraduate School. The major subdivisions of the model are:

- Air
- Air Defense Artillery
- Communications and Electronic Warfare
- Dismounted Infantry
- Field Artillery
- Ground Battle
- Tactical Movement
- Terrain.

The level of resolution runs the entire facet of the modern battlefield down to the individual weapon. The STAR Model provides a great deal of flexibility through user input data for the model. For example, as was performed in this study, the electronic warfare elements were given the ability to perform different types of EW actions against specified nets by manipulating EW.CREATE, the routine in which these attributes were read. This will be further discussed in Chapter III in this thesis. Output for the STAR model is equally flexible and can be manipulated by the user. This

lends itself to easier data analysis because the user can control the output, which consists of a detailed listing of indirect and direct fire, aircraft data, communication attempts, electronic warfare missions and periodic updating of the status and position of all units in the simulation.

Terrain in the STAR model is represented functionally as a series of hills which are ellipsoids in the horizontal cross section and have the characteristic Gaussian bell-shaped curve in the vertical cross section. Each hill has seven parameters which result in a parametric terrain surface represented at every point in the battlefield. Rivers, built-up areas, and foliage are also modeled. The communications module of the STAR has the capability to decrease the quality of communications through propagation loss due to foliage. However, the assumption was made that frequency modulated communications (30-76 Mhz range) are not significantly influenced by foliage and thus propagation loss calculations were not included. The height of terrain plays an important factor in the calculation of line of sight between two entities. In the STAR model the maximum height at any point on the terrain is the maximum height of all hills that have an influence at that point. Line of

sight(LOS) is computed beginning at the top of the observer or radio antenna. The maximum fraction of the target visible due to defilade is first computed and then every hill is checked between the observer and the target to determine whether any hill has further decreased target visibility. If the target visibility fraction decreases to zero, then LOS does not exist and any action concerning the appropriate entities is cancelled. For a more detailed description of terrain modelling in the STAR model, see Reference 1.

Events within the version of the STAR Model employed for this thesis, are dependent upon discrete time intervals. For example, the event STEP.TIME incrementally updates the position of every element on the battlefield and then checks line of sight between each pair of opposing forces. However, the most current version of the STAR model no longer depends upon the STEP.TIME concept, but rather the events are sequenced for each element. If LOS exists, then a time to detection is scheduled dependent upon numerous factors on the battlefield. If the time to detect is less that thirty seconds, a detect is scheduled, and an assessment is made to determine if the detection has

resulted in a lucrative target acquisition for either side. If a detect is not scheduled, the detector will try again within the next thirty second time interval to make a detection. Once all actions are completed within the scheduled time period, the internal time clock of the simulation is advanced and the detection process is initiated again.

Tactical movement within STAR is simulated by the ground movement routines which are responsible for updating the position of vehicles which are moving on the battlefield during the simulation. The movement routines are designed to allow a variety of different movement modes to interface with the terrain model. Reference 2 contains a detailed description of the ground movement routines utilized in STAR.

The STAR model was initially developed by Wallace and Hagewood [Ref. 3]. In their thesis, "Simulation of Tactical Alternative Responses", Wallace and Hagewood set up the initial STAR model which played a blue company in the defense under attack by a red battalion. The first addition to the original model was a field artillery module, the basis for this module provided by a thesis written by

Starner [Ref. 4]. In this thesis, Starner developed a two-sided field artillery stochastic simulation of both the red and blue battalion artillery.

Another module added to STAR was a route selection module which was based on a thesis by Kramer [Ref. 5]. In his work, he developed a deterministic simulation model for dynamic tactical route selection based upon the route selection technique used in the DYNTACS simulation model.

In his thesis, Broussard developed a dynamic model for the tank commander's target selection process, based on a survey of numerous tank gunners in the fields [Ref. 6].

Initially, communications on the battlefield was assumed to be of little consequence and a guaranteed presence on the battlefield. In separate, but related, efforts Haislip [Ref. 7] and Olson [Ref. 8] developed communications routines for addition to the STAR model. Single channel, frequency modulated (FM) communication routines were developed which now serve as a basis for the communications module which has been incorporated into the STAR model. In order for units to communicate, radios must be created for the entities within the model at the same time that they are created as battlefield entities. Haislip's thesis also

provided a basis for the electronic warfare routines which have been developed for the STAR model. These routines are discussed in detail in Chapter III of this thesis.

Current limitations of the model include the lack of engineer support and logistical support activities. These functions are considered as essential elements within the battlefield arena but to date have not been simulated within the model, however, they are currently under development. Another limitation to the STAR model is the lack of dynamic route selection by elements on the battlefield. Presently, units are assigned specified movement routes and with no flexibilty to alter from these routes. Also included in the limitations of the model is the inability of the electronic warfare module to simulate sweep jammimg. A detailed description of this electronic warfare module will be covered in the next chapter.

III. DESCRIPTION OF THE ELECTRONIC WARFARE MODEL

A. BACKGROUND

The use of electronics on the battlefield affords the commander the capability to control and maneuver his forces with great flexibility during battle. Therefore, communications have become especially important and essential in the command and control of elements on the battlefield. For example, when a target appears to be lucrative to several different field artillery weapon systems, a command decision must be made to allocate a particular weapon system upon the target. Information concerning this target must be transmitted to a decision maker, and in turn, after a decision is made, an allocation of the weapon system to be utilized against the target must be transmitted to the weapon user. These allocations are usually transmitted via some communications link.

Through the utilization of specialized equipment, communication transmitters can be intercepted and analyzed. Listening to and locating the source of the opposing forces communication devices can provide the tactical commander

with indicators about the enemy. These indicators may include the magnitude of the enemy force, the enemy's intentions, technical information for disrupting the enemy's electronic devices, and other information that may be useful in developing the order of battle. Intelligence derived from information obtained through the utilization of such specialized equipment, called Signal Intelligence (SIGINT), is an indispensible input to the commander's estimate. Direction finding equipment can provide approximate loctions of enemy radio and radar antennas, as well as artillery and rear echelon postions. This information can assist in determining enemy movements, disposition, and targeting data [Ref. 9]. This is but a small example of the capabilities and flexibility provided by that aspect of the battlefield called electronic warfare.

The increased dependence on communications at each level of command has created a strong concern for the survivability, dependability, and accuracy of any communications system. To properly safeguard communications from exploitation, electronic warfare measures must also be employed. Electronic warfare can be defined as any military action involving the use of electromagnetic energy to

exploit, reduce, or deny the enemy use of the electromagnetic spectrum. Terrain obstacles, transmission time and power output of the communications device employed, antenna direction, and movement all play important roles in the employment of electronic warfare [Ref. 9]. Electronic warfare can be divided into three categories:

1. Electronic Warfare Support Measures (ESM)
2. Electronic Countermeasures (ECM)
3. Electronic Counter-Countermeasures (ECCM)

These three categories are the fundamentals of electronic warfare doctrine and must be considered by the commander while making decisions on the battlefield. Electronic Warfare Support Measures (ESM) are the actions taken to search, intercept, locate, and identify radio transmissions. These actions are taken to provide the commander with threat recognition information and to assist him with the tactical employment of his forces on the battlefield. The routine EW.ROUTINE, which will be discussed in detail later in this chapter, passes the variables from the communications module to the various routines that simulate ESM.

Table 1: Fundamentals of Electronic Warfare

TYPE	SIMULATED IN MODULE YES	 NO
1. ESM		
Interception	X	
Identification	X	
Analyzing information gathered		X
Locating through direction finding	X	
2. ECM		
Jamming		
spot	X	
barrage	X	
sweep		X
Physical destruction		X
Deception		X
3. ECCM		X

EW.ROUTINE also provides the interface for the second fundamental of EW, Electronic Countermeasures (ECM). Electromagnetic counter measures are the actions taken to prevent or reduce the enemy's use of the electromagnetic spectrum. This is accomplished through jamming enemy transmissions, disruption of enemy transmissions by destroying the communications device, and deception. However, in the EW module only jamming is simulated. The third fundamental of EW, Electronic Counter-Countermeasures(ECCM), which is defensive electronic warfare, is not played in the module since it entails the use of electronic measures to counteract offensive EW [Ref. 10, 11]. Hence, ECCM is not discussed in this thesis. Table 1 contains a summary of the fundamentals of electronic warfare and which fundamentals are simulated in the module. The following section will discuss in detail how they are simulated in the electronic warfare module.

B. DESCRIPTION OF THE ELECTRONIC WARFARE MODULE

The electronic warfare (EW) module is a collection of Simscript Level II.5 programs that provides the necessary routines and events used to simulate electronic warfare in the Simulation of Tactical Alternative Responses (STAR)

model. The module contains several routines, events, and functions, however, these may be categorized in the following manner:

1. Initialization of entities.
2. Interface and electronic warfare functions.
3. Output.

A complete description of the routines and events in the EW module is contained in Appendix A. Appendix D contains the block diagrams associated with the routines and events in Appendix A.

Routine EW.INITIALIZE defines the nature of the EW characteristics that are to be used in the model. In this routine, the technical characteristics of the equipment simulating the electronic warfare entities are defined. For example, the jammer frequency bandwidth and the sweep rates of the frequency modulated scanners are read at this point. Further inputs to this routine are the decision parameters for the EW actions to be taken by the EW elements. Specifically, the type nets to be jammed or the elements to be located are input. Although not directly called by this routine, the communications routines within the communications module have a great deal of interface with`

the EW module. This interface is generated by the creation of the radio communication nets as entities in the STAR model. The communications module provides the communication nets to support the EW functions. Routine EW.INITIALIZE in Appendix A has a description of the assignment of electronic warfare actions against specific nets. The other initialization routine called by this module is EW.CREATE. In this routine, the individual electronic warfare elements are defined and assigned their technical attributes. Table 2 lists the different EW element types and their functions utilized by the EW routine. In the senario generated for this thesis, two identical electronic warfare platoons were created. Each consisted of three intercept stations, three direction finding stations, one jamming position and one analysis position. Thus these two EW routines, interfacing with routines and events from the communications module of the STAR model, were used to create the electronic warfare elements and assign them their characteristics.

Table 2: Electronic Warfare Elements

EW Element	Functions
Analysis	- maintains a list of EW targets.
	- accumulates net type identification data to be used for planning EW actions.
	- accumulates the report of successful missions from the DF control stations.
	- assigns jamming missions after the net type has been identified.
DF	- intercepts nets that have been identified as DF targets.
	- receives missions from the DF Control station.
	- attempts to locate a transmitting station whose net type has been identified.
	- reports DF mission results to the DF Control station.
DF Cntl	- assigns DF missions to the DF stations.
	- reports DF mission results to the analysis element.
	- receives DF mission results form the DF elements.
	- performs the same actions as the DF elements.
Intercept	- intercepts transmissions and reports to the analysis elements.
Jammer	- receives jamming missions from the analysis element.
	- intercepts nets for the purpose of jamming the net.
	- reports jamming mission results to the analysis element.

Table 3: EW Functions and Their Related Routines and Events

the table below lists the routines / events associated with the electronic warfare functions simulated in the EW module.

JAMMING	DIRECTION FINDING	INTERCEPTION
EW.ROUTINE	DF.ASSIGN.MISSION	BUS.PROB
JAM	DF.CALL	EW.ROUTINE
JAM.ASGN.MSN	DF.FIX	NEW.COMINT.RPT
JAMLOOK	DF.MON	PICKUP
LOOKTHRU	DF.REPORT	
TACDECIDE	DF.SHOT	
	EW.ROUTINE	
	LOB	
	TRIG	

To interface the routines that simulate electronic warfare with the communication routines in STAR, the routine EW.ROUTINE is used. This routine provides the initial link between the communications and all the other routines in which the basic fundamentals of EW are simulated. Routine EW.ROUTINE is called whenever a communications transmission is attempted within the communications module. Table 3 is a summmary of the routines involved in the simulation of the fundamentals of EW.

Initially, EW.ROUTINE checks for jamming, which will cancel all other EW functions. This is based on the assumption that while a jammer is active, intercept and direction finding attempts are rendered ineffective since their receivers will also be jammed while they are attempting to use the same frequency as the transmitting

station. EW.ROUTINE initially calls the routine JAMLOOK which determines if the net being used for transmission passed to the EW.ROUTINE is currently being jammed. If this is true, then JAMLOOK returns to EW.ROUTINE. However, if the net is not on the active target list of a jammer, the routine determines if the transmission is on a type net that has been identified and cleared jamming. If no jamming action is cleared for the net, the routine ends. However, if the transmission is communicating on a jammable frequency, then JAMLOOK determines if a jammer is available in the range of the transmission and able to tune to the frequency prior to completion of the transmission. If so, then a JAM event is scheduled by JAMLOOK and the routine returns to EW.ROUTINE. If no jammer is available, or the net is a type not cleared as a jamming mission, or if the jammer cannot "hear" or tune to the transmission frequency, or tune prior to transmission termination, then the routine JAMLOOK ends with the appropriate messages.

Upon returning from JAMLOOK, EW.ROUTINE determines the status of the transmission in relation to the jamming routines, and ends if the transmission is being jammed. Otherwise, EW.ROUTINE checks other EW actions that could be employed against the transmission.

If the transmission is on a net type that has been identified, then EW.ROUTINE calls the routine DF.MON to determine if any DF stations are tuned to the frequency of the transmission, awaiting a communications attempt. If not, then DF.MON returns to EW.ROUTINE. However, if any DF station is tuned to the transmission's frequency, then event DF.SHOT is scheduled for that station before returning to EW.ROUTINE.

EW.ROUTINE then compares the transmission's frequency with each intercept station's frequency. If the transmission's frequency is within the intercept band of any intercept station, EW.ROUTINE determines stochastically how long it will take the intercept station to detect the transmission. If the length of the intercept is longer than the transmission length, then no intercept action will take place and the routine ends. However, if the transmission's length is less than the time it takes to detect, then an intercept can take place and the routine PICKUP is called. The routine PICKUP is used to simulate the intercept function of electronic warfare.

The routine PICKUP first determines whether the transmission has been previously intercepted. If the

tranmission is a previous intercept, then the routine checks to see if the type of net over which the transmission is communicating is known or unknown. If the net type is unknown, then the routine compares the transmisson's length to a cutoff value. The purpose of this comparison is to simulate the interception of a transmission while it is in progress. Thus if the transmission's length is sufficiently long, then the transmission is intercepted and intelligence concerning the enemy can be collected. In this routine, this intelligence is equated to the number of times the net is intercepted. Eventually, as the number of the times the net is intercepted, this value increments to a threshold value. This threshold value is generated from the net type input of the routine EW.INITIALIZE. Once a threshold value is reached, the net type becomes "known" which is the second comparison the PICKUP routine makes. The ability of an analysis station to identify a net type based on a certain amount of intercepts is based on the assumption that each combat entity which communicates on the battlefield has an electronic signature that characterizes the net over which transmissions are attempted. For example, if communications are attempted from a centralized source near the forward

elements of the enemy to friendly rear forces, it could be assumed that a forward observer is sending targeting data to the artillery forces in the rear. Thus, information concerning the nature and location of the artillery forces could be obtained by intercepting the transmissions and locating the transmitters antennas. This information could be used to identify the net type.

If, initially, the net type of the target is known, the routine PICKUP determines whether direction finding actions are planned for the net type. If this is true and the DF stations are idle, then the routine calls the routine DFCALL, which is used to simulate the communication of orders to the DF stations. The routine DFCALL is used to send mission cancellations and mission assignments to the DF elements. When the net type is identified, the PICKUP routine increases the value of the appropriate variables and terminates. When the net type has been identified for the first time, the routine NEW.COMINT.REPORT is called. The routine NEW.COMINT.REPORT is used to simulate the actions of the direction finding control station. This routine checks the master target list of the analysis tank and if the net type has been intercepted for the first time, the routine

adds the net to the target list. However, if the net is already on the target list, then the routine ends. When the net type is identified for the first time, the routine TACDECIDE is called. This routine simulates the actions of the commander of the control station. In TACDECIDE, the eligible EW actions planned against the net are determined. If the net is to be jammed, the routine calls JAM.ASSIGN.MISSION to simulate the control station's assignment of a jamming mission to the jammer. If the net is not eligible for jamming, TACDECIDE ends and control of the simulation returns to the routine PICKUP. The routine PICKUP then ends with the appropriate messages and returns control of the simulation to EW.ROUTINE. EW.ROUTINE terminates at this point.

The final routine called from the EW module controls the EW output that is generated by the simulation. This routine is EW.DATA.ECHO and it basically prints a summary of the jamming, intercepting, and direction finding missions employed during the simulation For a more detailed description of all EW routines, see Appendix A.

IV. TEST METHODOLOGY

A. SCENARIO

The scenario utilized for the tests conducted in Chapters V, VI, VII, and VIII was executed on a 10 kilometer (north/south) by 15 kilometer (east/west) terrain box. The western half of the terrain is covered with rugged hills and the eastern half of the terrain consists of flat desert which eventually slopes into the hills. Refering to Figure 1, the only avenue of approach to the hills is an east-west pass through which red forces are expected to attack. The environment utilized is day with unlimited visibility. Smoke, dust and other battlefield conditions that limit visibility were not modelled.

The scenario has a blue battalion task force defending against a reinforced red Motorized Rifle Regiment. The blue battalion task force was organized to include a mixture of different weapon systems. The red force not only consists of a variety of force mixes, but includes several different electronic warfare elements. Chapter III has a description of the electronic warfare capabilities utilized in the scenario.

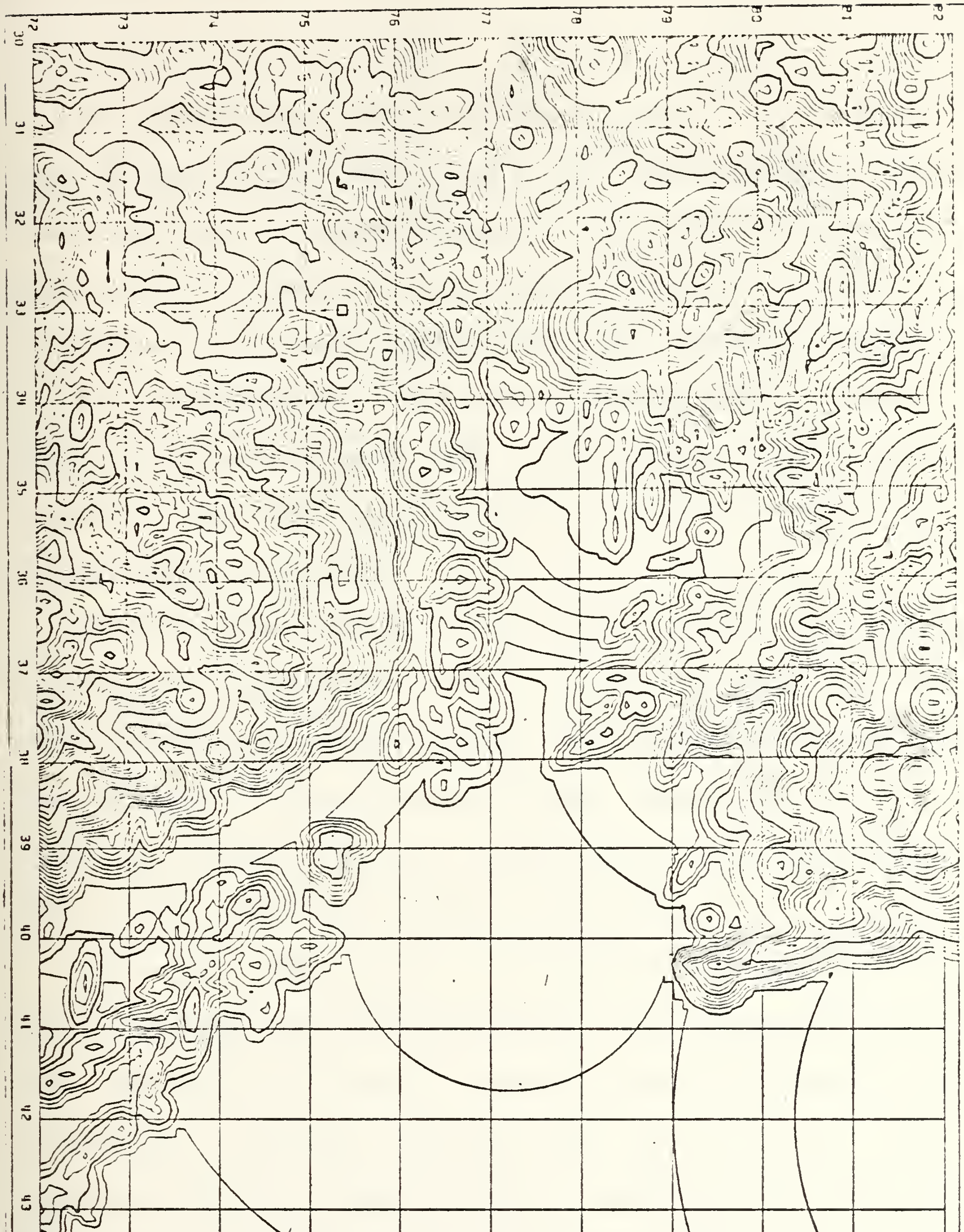


Figure 1: Terrain Map

The scenario has the blue force defending the mountain pass against the red force as it attacks from the east. The blue force has a company deployed on the forward slopes of each side of the pass. A third blue company is located in the center of the pass approximately two kilometers behind the forward companies. The aviation company deploys from an airfield in the blue rear area. The forward observers are located on the high ground above the two forward companies on each side of the pass.

The red forces advance in a two prong attack. The first force attacks the northern side of the pass while the second force attacks the southern slope. Each force consists of a Tank Company, three Motorized Rifle Companies, and a Electronic Warfare Platoon. A Tank Battalion follows the second force, ready to exploit a breakthrough.

The battle begins with a red artillery preparation as the red forces start moving towards their objectives and both blue and red artillery continue to fire throughout the engagement. Although varying from run to run, the electronic warfare elements usually engaged the blue forces with jamming actions approximately 700 seconds into the battle. Electronic warfare actions continued throughout the battle, and terminated upon simulation termination.

B. DESIGN OF EXPERIMENTS

Four experiments were selected to analyze the impact of jamming various blue forces communications assets. The first two experiments involved jamming the artillery communications. The artillery nets were chosen as targets due to the dependence of artillery on their FM communications to accomplish its mission. The first experiment involved jamming the forward observers' communications and the second involved jamming the fire direction centers.

The third experiment was designed to test the susceptibility of the movement control nets to jamming. In this experiment, the blue forces were required to receive permission to move on their FM communications nets. Jamming was then conducted on these nets.

The final experiment was designed to analyze the effect of relocating the EW elements in different positions. Terrain analysis was conducted and new EW positions were chosen that provided better jamming capability for the jammers.

V. EFFECT OF JAMMING BLUE FORCES ARTILLERY FORWARD OBSERVERS NETS

A. DESCRIPTION OF THE TEST

In this first test, analysis was performed to determine the effect that targeting the blue force's forward observers' radios with spot jamming has on the outcome of a simulated battle. Red forces jamming assets were directed at the blue forces forward observers because of the high volume of communications traffic that occurs on these nets. The measure of effectiveness(MOE) initially selected for this experiment was red forces survivability. The red force was composed of thirteen different systems which include tanks, armored personnel carriers(BMP), individual soldiers, anti-aircraft, and aircraft. The current STAR model computes percent survivors by dividing the total number of surviving systems after a simulation by the total number of systems that began the simulation. This percentage has very little value because it assumes that each system is of equal importance to the commander on the battlefield which is not true. For example, if air battles are not being played,

then an air defense system is of little value to the commander. Therefore, the determination was made that a system of assigning a military worth to each system must be used.

In an aggregated combat model such as STAR, there are many weapon systems that make up the force structure. A judgmental assessment of each weapon system must be made to give the analyst a better idea of what the actual outcome of a particular battle really means. Several methods used to arrive at assessments of the military worths of these weapon systems are field tests, questionnaires, and experience of the analyst. The technique used in this thesis was questionnaires.

Two students, Maressa and Rozman, distributed questionnaires to Army students at the Naval Postgraduate School asking for a subjective analysis of the military worth to the military commander of the various fighting systems used in the simulated battle. From these questionnaires, a military worth was assigned to each system-weapon type used in this analysis. Table 4 contains the Red Forces composition and their assigned military worths. Table 5 contains the Blue Forces composition and their assigned military worths.

Weighting is defined as a judgmental process in which a relative value is given to each system under examination according to the assessed value on the battlefield. Weighting is useful in that it is easy to apply to analysis of the outcomes of combat model simulations. One major flaw in the weighting system is that it fails to consider synergism. In our test, each system is given a relative worth at the beginning of the battle and this value never changes. It does not account for the fact that a combination of two weapon systems in a battle may increase the effectiveness for both systems. Also, as systems are destroyed during a battle, the value of the military worths of surviving systems could increase or decrease. However, changing the military worths during the course of the battle is a very complex task. Although the technique of weighting is not universally accepted, it provides the analyst with a valuable tool to do the analysis without adding excess effort, time and expense.

Table 4: Red Forces Structure and Military Worths

System Weapon Type	System Weapon Name	Description	Total Beginning Strength	Military Worth Per S-W
1-7	T-80	Tank	50	775
2-8	BMP	Armored Personnel Carrier	60	250
3-3	SA-7	Short-Range Air Defense Weapon	12	400
3-13	RPG	Anti-Tank Weapon	54	50
3-14	AK-74	Individual Weapon	288	150
3-15	RPK-74	Machine Gun	108	100
4-1		Forward Observer	8	600
4-2		E-W Element	16	200
4-5		Mortar	24	200
4-6		Mortar	6	450
4-7		Artillery	6	750
5-4	HIND	Attack Helicopter	24	999
6-9	ZSU-X	Air defense Weapon	6	725

Table 5: Blue Forces Structure and Military Worths

S-W Type	S-W Name	Description	Beginning Strength	Military Worth
1-1	MPG	Mobile Protected Gun	16	775
2-3	HMMWV	Armored Personnel Carrier	26	250
2-4	TOW	Anti-Tank Weapon	10	800
3-2	Stinger	Short Range Air Defense Weapon	6	700
3-6	Dragon	Medium Range Air Defense Weapon	24	400
3-10	M-16A2	Individual Weapon	102	50
3-11	M60	Machine Gun	24	150
3-12	M203	Grenade Launcher	24	100
4-1	FIST	Forward Observer	10	600
4-2	81mm	Mortar	9	200
4-3	107mm	Mortar	6	450
4-4	155mm	Artillery	8	750
5-1	AAH	Attack Helicopter	10	999
5-2	ASH	Support Helicopter	6	500
6-5	LADS	Light Air Defense Weapon	3	725

As a result of the weighting system, the choice of MOE was changed to percent remaining military worth. To compute percent remaining military worth, the total military worth and the remaining military worth must be computed. The following example demonstrates that computation. Suppose the red force is composed of 3 systems: tanks, armored personnel carriers (BMP's) and anti- aircraft weapons (RPG's). The initial strengths are given in Table 6. Refering to Table 6 for computations, the initial military worth equals 56450. If after a simulation the number of surviving system weapon types are: 10 tanks, 10 BMP's, and 2 RPG's, then the remaining military worth is 10350. The percent remaining military worth equals 18%.

Table 6: Computation of Military Worth

		INITIAL		TERMINATION	
SYSTEM	MIL WORTH PER UNIT	# IN UNIT	MIL WORTH	# IN UNIT	MIL WORTH
TANK	775	50	38750	10	7750
BMP	250	60	15000	10	2500
RPG	50	54	2700	2	100

Total Military Worth = $\sum$(# in unit) x (Mil Worth per unit)
Military Worth(initial) = 56450
Military Worth(termination) = 10350

Remaining military worth = MW(initial)/MW(termination

Remaining Military Worth = 10350/56450 = .18

If the weighting system had not been used the percentage of survivors remaining would be 22/164 which equals 13%. A FORTRAN program was written which will take the outcome of any number of simulations and convert the survivor percentages to remaining military worth percentages.

B. RESULTS AND CONCLUSIONS

If the radio transmissions of the blue forces forward observers are jammed, this would infer that the number of calls for artillery fire would decrease, therefore causing the red force's casualties to decrease. To analyze the actual effect of targeting the forward observers, a two sample inference test was used. The null hypothesis is that the mean of a sample of ten runs with no jamming action occuring is equal to the mean of a sample of ten runs with spot jamming directed at the forward observers. The alternate hypothesis is that the mean of the spot jamming sample is greater than the mean of the no jamming sample. Data used for this test is included in Table 7. The results of the inference test are included in Table 8. The test is analyzed at several levels of significance. A FORTRAN program was written to compute the T-statistic and test the hypothesis at any designated level of significance.

Appendix B contains a detailed description of the two sample inference test procedure.

At the level of significance of .10, we can conclude that implementation of jamming against the blue forces forward observers increases the remaining military worth of the red forces. The application of the nonparametric U-Test substantiates this claim. See Table 9. A detailed description of the non-parametric U-Test is included in Appendix C.

Table 7: Percent Remaining Military Worth Red Forces

Run #	Jamming Forward Observers	No Jamming
1	36.7	38.2
2	37.7	37.2
3	43.2	37.2
4	40.5	36.3
5	37.7	38.9
6	37.7	36.6
7	38.5	34.1
8	37.2	38.6
9	38.5	38.0
10	35.5	36.4

Table 8: Inference Test Forward Observers Jammed

Using data from Table 7, the following two sample inference test was conducted:

1. $Ho: u1=u2$
2. $H1: u1>u2$
3. $t=1.439$
4. $t(.95,18) = 1.734$
   $t(.90,18) = 1.330$
   $t(.85,18) = .862$
   $t(.80,18) = .534$
5. At the .05 level of significance, we cannot reject the hypothesis that the means of the two samples are equal, however, at the level of significance of .10, we can reject the hypothesis that the means are equal.

Table 9: U-Test for the Forward Observer Data

1. $Ho: u1=u2$
2. $H1: u1>u2$
3. Critical region: $z<-z(.05) = -1.645$
4. Computations
   $U1=84.5-(10x11)/2 = 29.5$
   $E(U1) = 50$
   $var(U1)=(10x10x21)/12 = 175$
   $z=(29.5-50)/\sqrt{(175)} = -1.55$
5. At this level of significance, $-z(.05)=-1.645$, this is less than -1.55 therefore we do not reject the null hypothesis. However, $-z(.10) = -1.282$ which is greater than -1.55 which means that at the level of significance of .10 we would reject the claim that the means of the two samples are equal and conclude that jamming affects the percent remaining military worth of the red forces.

The result expected was a definitive increase in the remaining military worth of the red forces. The statistical analysis demonstrates a change in the remaining military worth, but the amount is not as much as anticipated. There are some contributing factors to this result. In this scenario, the blue artillery is not the major combat threat to the red forces. The artillery was very active but it was called into the battle too early and it's impact was less than expected. The scenario was set up for an air, air defense battle, therefore, priority was given to the air and air defense systems. Since air power was the primary killing vehicle, air and air defense actions were initiated early in the battle. The combination of these factors contributed to the decreased effectiveness of the artillery in the simulations used in the analysis.

VI. EFFECT OF JAMMING THE FIRE DIRECTION CENTERS

A. DESCRIPTION OF THE TEST

In this test, the target of spot jamming is the Fire Direction Centers(FDC). There is a very high volume of communications traffic at each of the FDC's because of the volume of the number of calls for fire made by the blue forces artillery forward observers. This fact makes the FDC's prime targets for spot jamming. Since jamming should decrease the number of calls for fire processed at the FDC's, then the number of red casualties should decrease.

B. RESULTS AND CONCLUSIONS

Again, a two sample inference test is used to test the effectiveness of targeting the FDC's for spot jamming. The two samples used were ten runs with no jamming action occuring and ten runs with spot jamming directed at the FDC's. The expected results are an increase in the number of red survivors and an increase in the remaining military worth. Data used in this test is included in Table 10. The results of the T-test and the U-test are included in Tables 11 and 12.

From the inference test, we can conclude that jamming the Fire Direction Centers does not affect the percent of remaining military worth of the red forces. The raw data suggest that there are small changes in the percent remaining military worths and by further investigation, it was determined that the means of the two samples were equal at the third decimal place. In applying the U-test we also conclude that the means of the two samples are equal.

These results are not surprising since the jamming was targeted against the radio transmissions coming out of the Fire Direction Centers. Since the FDC's are not required to respond to all calls for fire before scheduling artillery fire, the artillery actions were not impeded by the jamming and the number of casualties and military worths were not affected. Also, the FDC's have a wire net available that is not susceptible to jamming.

It appears that jamming was ineffective in these runs, however, when the output from each run is examined, it is discovered that the jamming was very active but it did not affect the outcome of the battle in terms of overall red casualties and remaining military worth. In the runs where no jamming was conducted, very few casualties were incurred

as a direct result of the artillery, therefore, jamming the artillery nets would have little effect on the overall outcome of the battle.

Table 10: Percent Remaining Military Worth Red Forces

Run #	Jamming Fire Direction Centers	No Jamming
1	38.2	38.2
2	36.9	37.2
3	36.7	37.2
4	36.3	36.3
5	37.1	38.9
6	37.2	36.6
7	36.3	34.1
8	37.6	38.6
9	37.9	38.0
10	36.4	36.4

Table 11: Inference Test Fire Direction Centers Jammed

Using data from Table 10, the following two sample inference test was conducted:

1. Ho: u1=u2
2. H1: u1>u2
3. t = -.182
4. t(.95,18) = 1.734

   t(.90,18) = 1.330

   t(.85,18) = .862

   t(.80,18) = .534
5. We cannot reject the hypothesis that the means of the two samples are equal at any of the levels of significance.

Table 12: U-Test For The Fire Direction Center Data

1. Ho: u1=u2
2. H1: u1>u2
3. z =.794
4. -z(.05) = -1.645
5. Since the z statistic computed using the U test procedure is positive, it will always be greater than -z(alpha) therefore we will never be able to reject the hypothesis that the means are equal.

VII. EFFECT OF JAMMING THE MOVEMENT CONTROL NETS

A. DESCRIPTION OF THE TEST

The purpose of the next test was to analyze the effect of jamming the movement control nets. In this test, two sets of runs were used. In the first set of runs, jamming was directed at these nets. Since the movement of units was restricted, all commanders must radio their commander and ask for permission to move any units. Disruption of these nets by jamming should impair the communications ability of the blue forces and possibly leave the blue forces vulnerable to an attack. If the jamming is successful, there should be a decrease in the blue forces military worth and an increase in the red forces military worth. Table 13 contains the data used for this experiment. Results of the inference test are included in Table 14.

B. RESULTS AND CONCLUSIONS

When the T-test was applied to the data for these runs, it was discovered that there was no justification to reject the hypothesis that the mean of the sample, when jamming was conducted, was equal to the mean of the sample when no

jamming was conducted. However, when the raw data was analyzed, a peculiar result was noticed. When the movement of the blue forces was restricted and the movement control nets were jammed, the blue units never obtained permission to move. Hence, the blue forces remained in their initial positions. The red forces, ignoring the position of the blue forces, continued to move to their phase line beyond the blue force position. This left the red forces in a precarious postion because the surviving blue forces remained on the high ground and those units had terrain superiority over the red forces. The red force tanks moved into a position where the blue forces had excellent fields of fire. The result was a near complete destruction of the red force tank assets. The T-test proved to be inconclusive because the number of BMP's surviving increased and the number of tanks decreased thus causing direct tradeoffs in the surviving military worth. When the raw data is looked at, there is no basis for saying that the blue forces military worth decreased as was expected. There are some small changes in the actual blue survivors but the differences are so small that no conclusion can be drawn. These results do show that the effect of restricting

movement of the blue forces is scenario dependent. If the initial positions of the blue forces had not been as tactically sound as they were, the non-ability to move their units could have been disastrous. Since the positions chosen were better than the secondary positions, the opposite result was obtained.

Table 13: Percent Remaining Military Worth Red Forces

Run #	Jamming Movement Control Nets	No Jamming
1	32.1	36.1
2	34.8	34.3
3	31.4	32.5
4	32.5	40.5
5	37.8	31.7
6	31.7	31.7
7	43.5	42.1
8	32.3	37.4
9	34.0	37.0
10	30.4	31.5

Table 14: Inference Test Movement Control Nets Jammed

Using data from Table 13, the following two sample inference test was conducted:

1. Ho: u1=u2
2. H1: u1>u2
3. t = -.827
4. t(.95,18) = 1.734

   t(.90,18) = 1.330

   t(.85,18) = .862

   t(.80,18) = .534
5. We cannot reject the hypothesis that the means of the two samples are equal at any of the levels of significance.

VIII. EFFECT OF REPOSITIONING THE JAMMING STATIONS

A. DESCRIPTION OF THE TEST

Positioning of the jamming stations can have a great impact on the effectiveness of the jamming. To analyze the effect of repositioning the jammers, new positions were chosen for the EW elements. The initial positions chosen for the jamming stations were forward in the battle area, therefore, new positions were chosen that were a greater distance from their jamming targets. The expected results is that the jamming should be less effective at the second positions and the red forces' military worth will decrease.

B. RESULTS AND CONCLUSIONS

The analysis performed compared the spot jamming directed at the forward observers in the initial positions with the spot jamming directed at the forward observers with the jammers repositioned. Data for the test is included in Table 15. Results of the T-test are included in Table 16.

When the T-test was performed on the repositioned data, the null hypothesis that the means are equal is rejected at the level of significance of .05 which implies that jamming

from the new positions decreases the military worth of the red forces. The number of direction finding fixes was greater at the first position, therefore, the number of potential targets for artillery fire was higher. When the blue forces survivor information was analyzed, it was discovered that their strength totals also did not change appreciably, however, if the direction finding fixes were passed on to the artillery units, there would be a significant decrease in the blue force remaining military worth. The conclusion can be drawn that the correct positioning of the jamming stations and the interaction of the direction finding module with the artillery module are important for the EW module to have an effect on the outcome of the battle.

Table 15: Percent Remaining Military Worth Red Forces

Run #	Jamming Forward Observers First Location	Jamming Forward Observers Second Location
1	36.7	35.7
2	37.7	36.3
3	43.2	35.9
4	40.5	37.1
5	37.7	36.1
6	37.7	36.0
7	38.5	37.2
8	37.2	38.4
9	38.5	34.8
10	35.5	38.4

Table 16: Inference Test Jammers Repositioned

Using data from Table 15, the following two sample inference test was conducted:

1. Ho: u1=u2
2. H1: u1>u2
3. t = 2.234
4. t(.95,18) = 1.734

   t(.90,18) = 1.330

   t(.85,18) = .862

   t(.80,18) = .534
5. We can reject the hypothesis that the means of the two samples are equal at the .05 level of significance.

IX. SUMMARY

The scenario used for the simulations in the course of this thesis was a blue forces brigade defending against an attacking red forces regiment. The blue forces were in defensive positions in a mountainous area and the red forces were attacking across a flat, open area. The outcome of the battle was never in question because the blue forces defensive positions were excellent against the red forces attack routes.

The purpose of this thesis was to analyze the effect of implementing EW against the blue forces communications nets. The first nets jammed were the blue forces artillery forward observer nets. When these nets were jammed, the forward observers had great difficulty transmitting their calls for fire, therefore causing less red casualties to occur and ultimately an increase in red forces military worth. Statistical testing confirmed this result.

The second test involved jamming the fire direction center nets. From subjective analysis of the data from the ten replications and comparison with the ten runs where no jamming was conducted, the conclusion is that jamming the

fire direction nets was not an effective tactic for the red forces to use to affect the outcome of the battle in the desert scenario.

In the third test, movement of the blue forces was restricted. When jamming was conducted against the movement control nets, blue forces commanders never received permission to move their units. This proved to be disastrous for the red forces tank assets because the blue forces' initial positions were excellent for a tank engagement with the red forces. The result was an almost complete destruction of the red forces' tank assets.

In the next test, the positions of the jammers was analyzed. New positions that were not as far forward were chosen and EW was conducted at these positions. The result was that the jamming conducted from the second positions was not as effective as the jamming conducted at the positions closest to the EW targets.

An overall analysis of the direction finding capability reveals that this portion of the EW module is very active. Many location fixes were performed by the red forces, however, the DF module is passive in nature, i.e. there was no interaction with other portions of the STAR model. To

analyze the effect that the direction finding module has on the outcome of the battle simulation, location fixes must be passed to the artillery module for possible scheduling of fire missions. If this action is accomplished, the direction finding capability would greatly affect the outcome of the battle and further enhance the jamming portion of the EW module.

Overall, in the desert scenario, the EW module of STAR has very little effect on the outcome of the simulation. The module, however, does perform jamming and direction finding in a systematic manner, and, in a different scenario, the module may produce different results. Further enhancement of the model to allow for interaction of the direction finding location fixes with the artillery module will greatly increase the impact of EW on the outcome of the simulated battle.

APPENDIX A

ELECTRONIC WARFARE ROUTINES

This appendix contains a summary of the Electronic Warfare routines utilized by the EW module to simulate the EW actions employed on the battlefield. Each routine is described in detail, accompanied by a block diagram of the flow of logic in the routine. Also included in the description of the routines are input and output variables, routines called by the routine being described, and a list of routines and events that utilize the routine described.

The routines COMMO.ATTEMPT and RCV.SIG are routines utilized by many of the routines in the EW module. These routines originate in the communications module and therefore are not discussed in this appendix, however, a brief description of their purpose is provided.

A. COMMUNICATION ROUTINES

COMMO.ATTEMPT is an event that simulates the attempt by a transmitter to transmit a message. Before a message can be transmitted, the line of sight between the transmitter and the receiver must be determined, as well as the power

output of the transmitter and the propagation loss due to terrain (when applicable). If any of these computations are determined to be insufficient, then the COMMO.ATTEMPT is cancelled. The routine RCV.SIG is used to determine the ability of the receiving station to hear the transmitting station.

B. ROUTINE BUS.PROB

This routine provides EW.ROUTINE with a value with which to compare a probability generated by an uniform(0,1) random number generator. EW.ROUTINE uses this value to determine if the interceptor is busy.

INPUT VARIABLES

none

OUTPUT VARIABLES

PR.BUS	The probability that the interceptor operator is busy.

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
EW.ROUTINE	none	none

No block diagram is provided for this routine.

C. EVENT DF.ASSIGN.MISSION

DF.ASSIGN.MISSION is an event that is used to simulate the initiation of a new DF mission or the acknowledgment of a cancellation of a DF mission that has exceeded its alloted time to be completed. Initially, DF.ASSIGN.MISSION determines if the mission passed to the event as the variable DFMISSION is a new, old, or cancelled mission. If the DF mission passed to this event is new, then event DF.SHOT is scheduled in exponential time units. Whenever the DF mission passed to the routine is an old mission, the event ends because the mission is already assigned to the DF stations. If the DF mission is a cancelled mission, the event acknowledges this and passes the information to the DF elements by calling the routine DF.FIX with special values. The event returns to DFCALL upon termination.

INPUT VARIABLES

DFSITE	Pointer used to identify the electronic warfare entity that is simulating the df action.
DFMISSION	Pointer used to denote the current transmission being evaluated in the routine.

OUTPUT VARIABLE

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
DFCALL	DF.SHOT	none

Figure 2 is a block diagram of this event.

D. ROUTINE DFCALL

The routine DFCALL is called by the routine PICKUP to determine the current disposition of the DF stations. DFCALL determines if the DF stations are idle or currently working on a mission. If the elements are idle, then DFCALL assigns a mission to the transmission passed to it by PICKUP by scheduling a DF.ASSIGN.MISSION. After this scheduling, a COMMO.ATTEMPT is scheduled to simulate the assignment of a DF mission by the DF control station to its subordinate units. However, if the DF stations are working on a mission, then DFCALL compares the current simulation time to the scheduled end time of the mission. If the current mission has a scheduled end time exceeding the simulation time, then the current mission is still in progress and must continue to be executed. Therefore the DF mission that has been passed cannot be assigned and the routine terminates. However, if the scheduled end time is less than than the current time, then the DF stations cannot successfully complete the mission in progress because the transmission is

DF.ASSIGN.MISSION

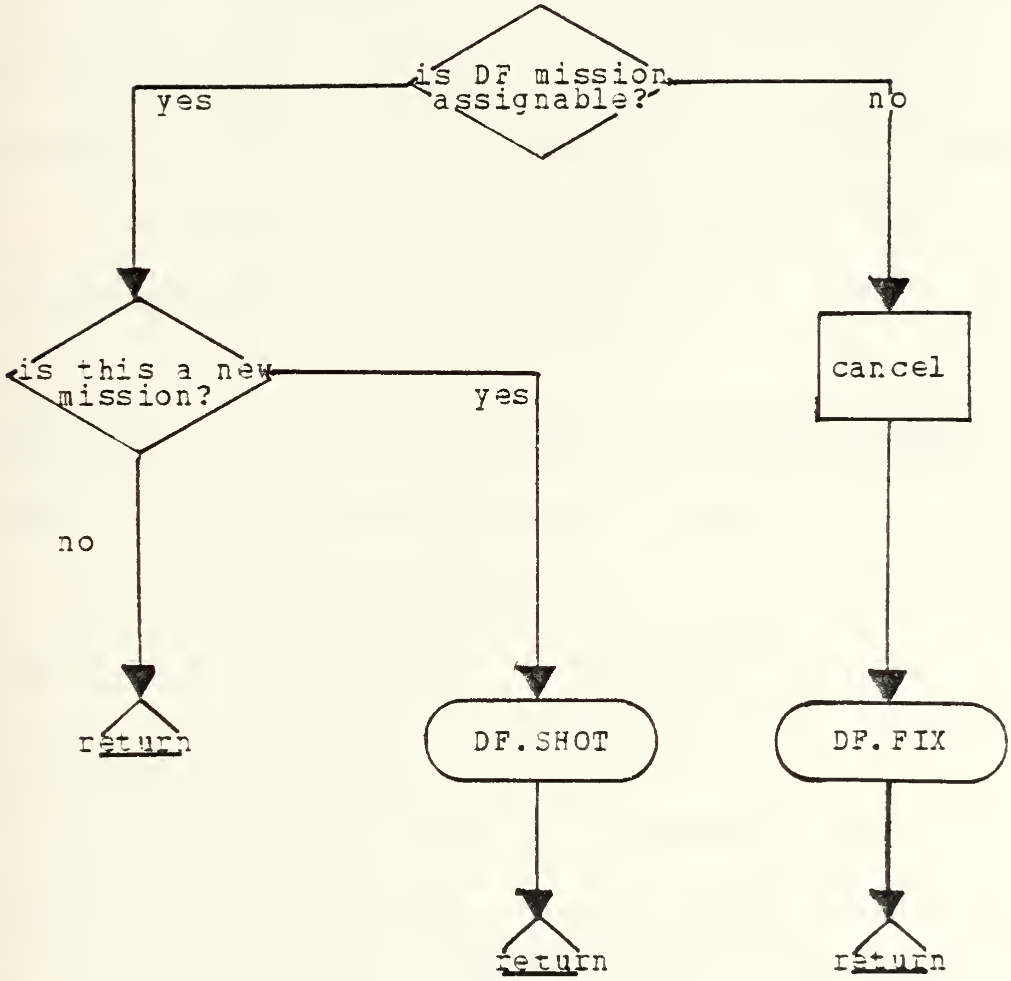


Figure 2: Block Diagram (Routine DF.ASSIGN.MISSION)

completed. Thus the mission in progress is cancelled and a new mission is assigned in the same manner described above, The routine DFCALL ends and returns back to the routine PICKUP.

INPUT VARIABLES

DFMISSION	Pointer used to denote the current transmission being evaluated in the routine.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
PICKUP	DF.ASSIGN.MISSION COMMO.ATTEMPT	none

Figure 3 is a block diagram of this routine.

E. ROUTINE DF.FIX

This routine is used to accumulate and coordinate direction finding attempts. The routine accumulates the Line of Bearings (LOB) taken by each of the DF stations in the platoon. When sufficient LOB's have been taken, the routine calls the routine TRIG to calculate an estimated position for the transmitting station. After a position is calculated, the routine schedules a COMMO.ATTEMPT to simulate the transmission of a successful direction finding

DFCALL

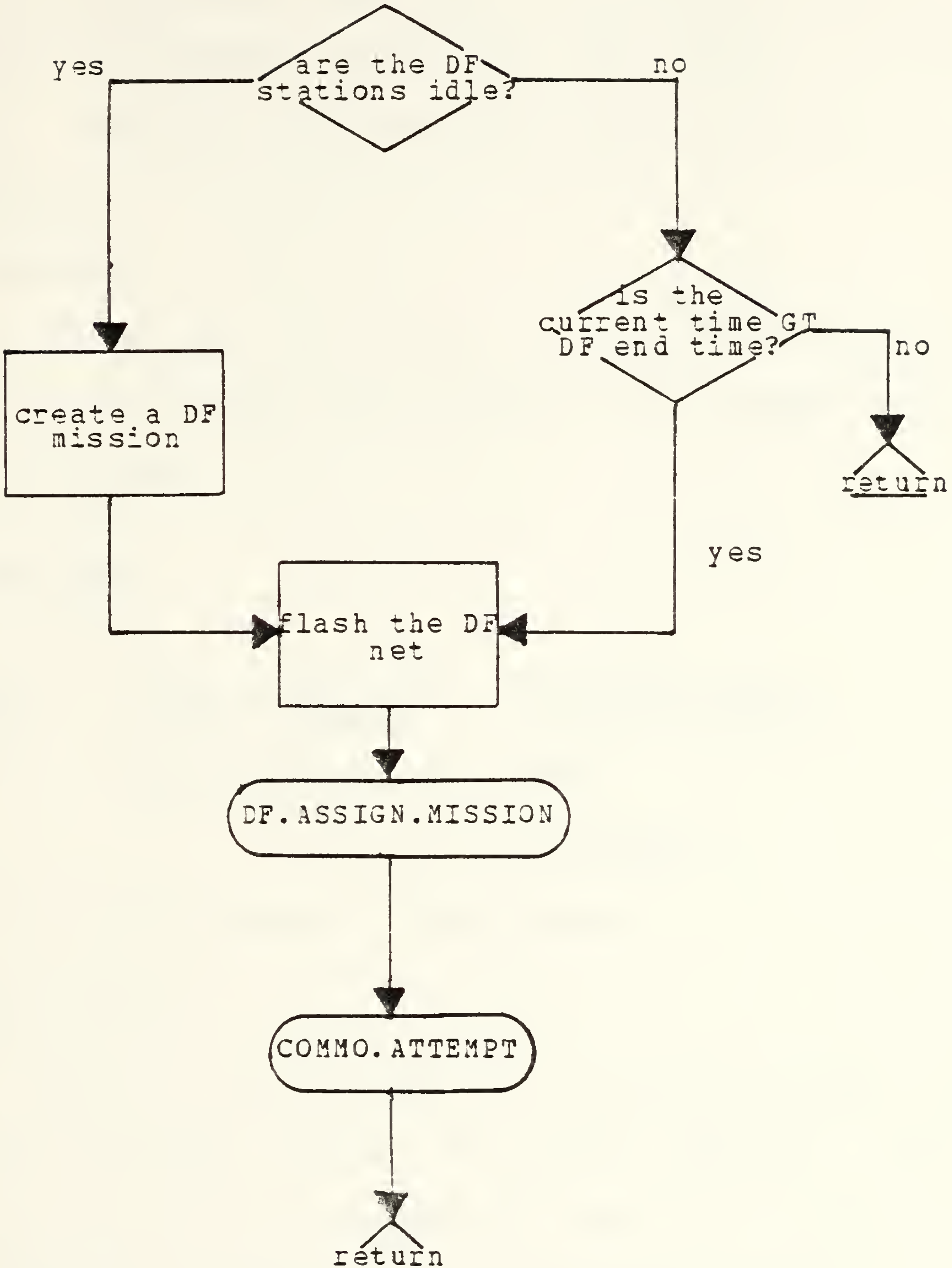


Figure 3: Block Diagram (Routine DFCALL)

attempt. This message is usually sent to the analysis position in the platoon. This event is simulated by calling the routine DF.REPORT, after which the routine DF.FIX terminates. However, if enough LOB's are not obtained the routine ends.

INPUT VARIABLES

LOBMSG	Pointer used to represent the current direction finding mission and direction find elememt being evaluated.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
DFCALL	COMMO.ATTEMPT	TRIG DF.REPORT

Figure 4 is a block diagram of this routine.

F. ROUTINE DF.MON

This routine is called by the routine EW.ROUTINE to verify the monitoring status of the DF elements. The routine terminates with messages that report the status of the DF station in relation to the transmission passed to the routine. The DF stations will be reported to be in one of

DF.FIX

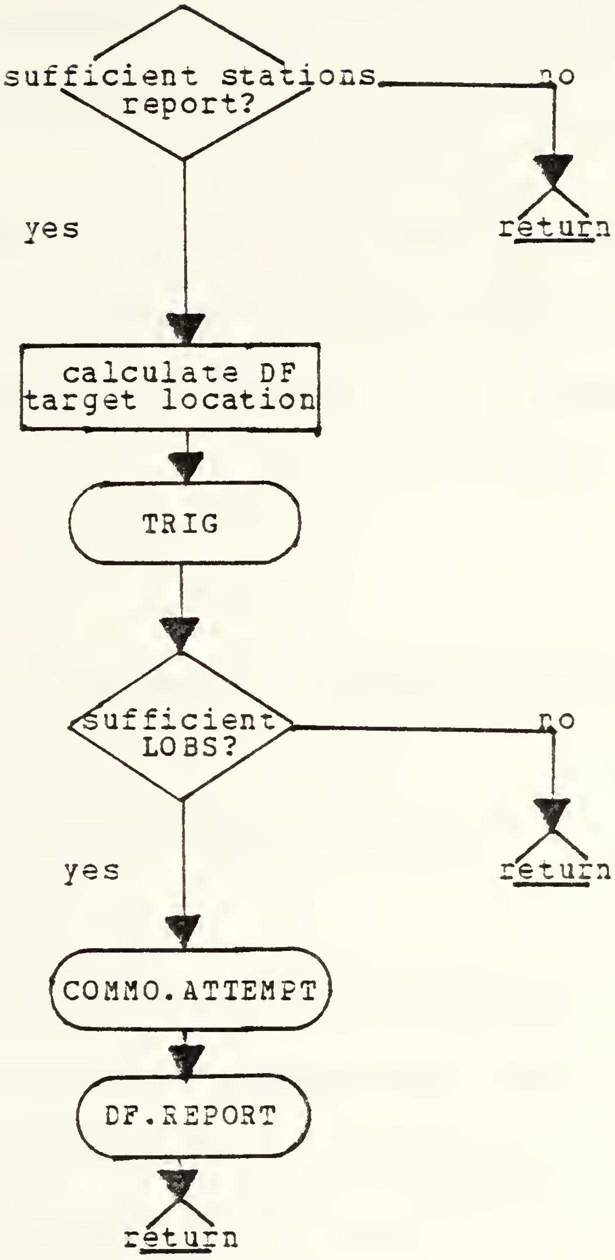


Figure 4: Block Diagram (Routine DF.FIX)

three modes: monitoring, not monitoring, or tuning to the transmission's frequency. If the transmission attempt is made on a net type that has DF actions planned but no mission is presently assigned, a DF.SHOT is scheduled prior to the termination of the routine.

INPUT VARIABLES

DFSITE	Pointer used to denote the electronic warfare element whose monitoring status is being verified.
TGTRT	Pointer used to represent the transmitting station.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
EW.ROUTINE	DF.SHOT	none

No block diagram is provided for this routine.

G. ROUTINE DF.REPORT

This routine is called by the routine DF.FIX to simulate the receipt of a successful DF mission from the DF control station by the analysis station. Initially the routine checks to see if the transmitter, in the form of the pointer DFRPTMSG, is contained on the master target list of the analysis element. If the transmitter is on the list, the

routine terminates. If not, the routine adds the transmitter to the target list, terminating the routine.

INPUT VARIABLES

ANLSET	Pointer used to indicate the DF station that located the transmission's source.
DFRPTMSG	Pointer used to indicate the DFMISSION that was sucessfully terminated.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
DF.FIX	none	TACDECIDE

No block diagram is provided for this routine.

H. EVENT DF.SHOT

This event is used to simulate the direction finding attempt by the DF stations and the subsequent 'analysis' performed by the DF elements. Initially, the status of the variable DFMISSION is checked to determine if this mission has been previously completed, initiated too late, or assignable. If the mission is complete, the event ends because the mission had been completed, and therefore no need to reassign the mission exists. If the DF station is in an idle mode, this is an indication that the DF station

attempted to locate the transmitting station after the transmitting station had completed its transmission, and, thus, the DF station was too late in its DF attempt and the routine ends. However, if the transmitter is still active, event DF.SHOT calls the routine RCV.SIG to determine if the DF station has the ability to intercept the transmission. If this occurs, then the routine LOB is called to simulate the line of bearing obtained by the DF station. The routine then simulates the transmission of a mission complete message by scheduling a COMMO.ATTEMPT and calling the routine DF.FIX, after which the routine ends. Had the DF station been unable to intercept the transmission, the event DF.SHOT would have been terminated.

INPUT VARIABLES

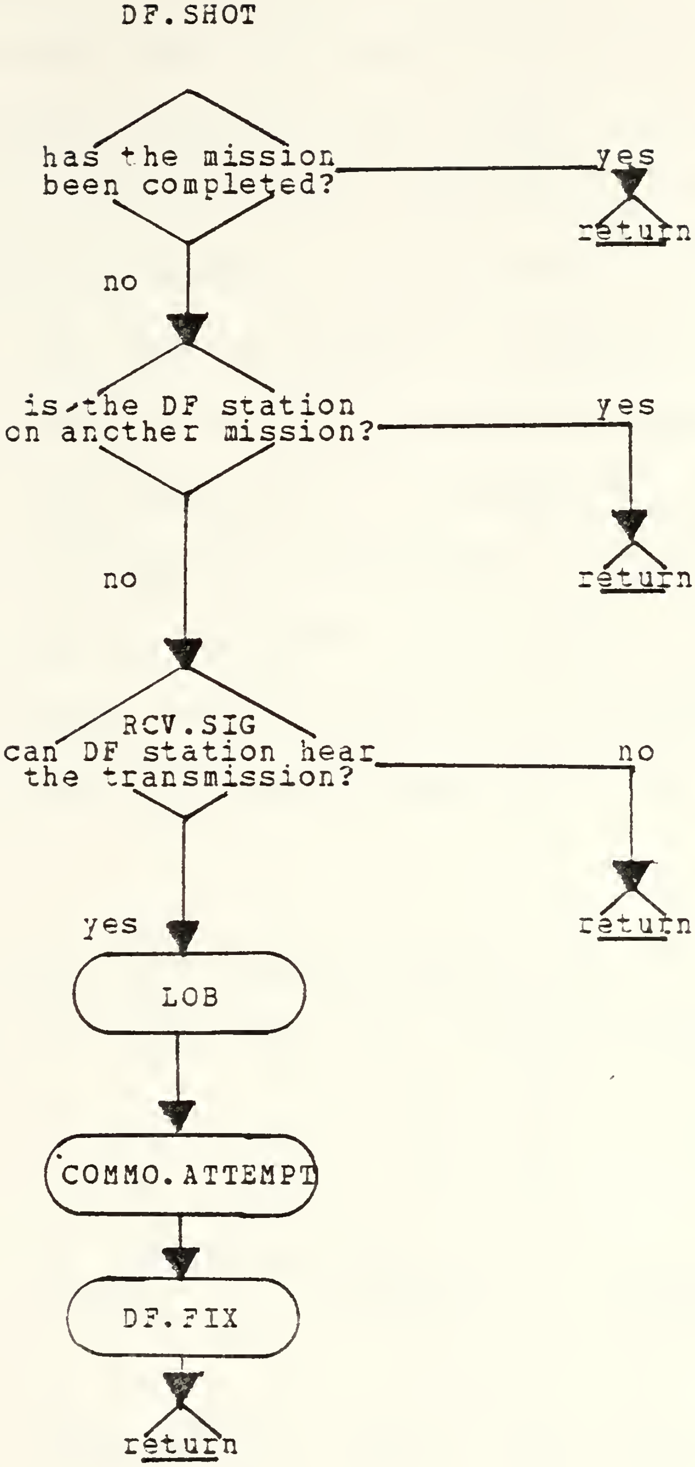
DFSITE	Pointer used to denote the DF element that is being called upon to locate a transmission.
DFMISSION	Pointer used to indicate the transmission.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
DF.ASSIGN.MISSION	COMMO.ATTEMPT	RCV.SIG
DF.MON		LOB

Figure 5 is a block diagram of this event.



DF.SHOT
has the mission been completed?
yes
return
no
is the DF station on another mission?
yes
return
no
RCV.SIG
can DF station hear the transmission?
no
return
yes
LOB
COMMO.ATTEMPT
DF.FIX
return

Figure 5: Block Diagram (EVENT DF.SHOT)

I. ROUTINE EW.CREATE

The routine EW.CREATE reads the technical attributes of the electronic warfare elements and assigns their EW functions. Initially, the number of EW elements is read. This is used to define the amount of storage space required by the EW entities. For each EW element, the name of the element is read along with a 1 or 0 in a specific column to indicate the element's EW capability. A example of a line of input for each EW type element is provided in Table 17. This type of data structure generates flexibility for the data input. If necessary, an EW element can be given the capability to simulate more than one EW function.

Table 17: Electronic Warfare Element Data

Station	EW Element	Intercept	Jam	DF	DF Cntl	Analysis
Intercept	931	1	0	0	0	0
Jam	937	0	1	0	0	0
DF	934	0	0	1	0	0
DF Cntl	936	0	0	1	1	0
Analysis	938	0	0	0	0	1

High Frequency	Low Band	Configuration		
		Radio	Antenna	Channels
30000	75000	1	1	2

After the EW function is read, the technical characteristics of the EW element are read. This includes

the upper and lower bounds of the operating frequency of the EW element as well as the radio and antenna configuration of that EW element. These configurations define the power output of the radio utilized by the EW element and the height of the antenna. Based on the elements EW capability, additional data is read. For example, if the element is a DF control station, the elements controlled by the station are read. Similiarily, the elements which report to the analysis station are also read at this point. Once all the EW elements have been read, the routine terminates. Figure 6 contains a sample of the data set, NEWTHES(EWDATA), utilized by the simulation for this thesis.

INPUT VARIABLES

Variables that represent the attributes of the EW elements are read into the simulation in this routine.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
BIG.MAIN	none	EW.DATA.ECHO

No block diagram is provided for this routine, however Figure 6 is an example of the input data set utilized.

```
A    16                                  NUMBER OF EW.POSITIONS
 931     1     0     0     0     0              INT POSITION 1
   30000 75000          1        1      2           TECH. CHAR
 932     1     0     0     0     0               IN POSITION 2
   30000 75000          1        1      2           TECH. CHAR
 933     1     0     0     0     0              INT POSITION 3
   30000 75000          1        1      2           TECH. CHAR
 934     0     0     1     0     0               DF POSITION 1
   30000 75000          1        1                  TECH. CHAR
 935     0     0     1     0     0               DF POSITION 2
   30000 75000          1        1                  TECH. CHAR
 936     0     0     1     1     0           DF POSN 3/DF CNTL
   30000 75000          1        1                  TECH. CHAR
   10      3     931    932    933        NET AND INTCP STA'S
                                               FOR DF CONTROL
   3      934      935    936              DF STATIONS IN NET
 937     0     1     0     0     0                      JAMMER
   30000 75000          3        1                  TECH. CHAR
 938     0     0     0     0     1           ANALYSIS POSITION
   5   931   932   933   936   937          REPORTING STATIONS
```

Figure 6: Data set NEWTHES(EWDATA): Routine EW.CREATE

J. ROUTINE EW.DATA.ECHO

This routine provides a summary of the EW actions that have occurred during the simulation. Upon termination of the simulation, the routine initially provides a summary of the EW elements capabilities and the electromagnetic frequencies against which the EW elements performed EW actions. The routine also provides a summary of the intercept, direction finding, and jamming actions.

<u>INPUT VARIABLES</u>

none

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
STOP.SIMULATION	none	none
EW.CREATE		

No block diagram is provided for this routine.

K. ROUTINE EW.INITIALIZE

Routine EW.INITIALIZE defines the specific EW actions to be employed against specfic type nets. Initially, the routine reads the values of the variables that define the parameters of the different EW functions. This includes the maximum number of DF missions that a DF station can operate, the tuning times for DF monitoring, and times for the length of jamming. Then the routine reads in the net type and the specfic EW action that is planned for that net. Figure 7 has a sample of the data set utilized by this routine. The first two rows indicate the average number of times the net must be intercepted in order for the net to be interpreted as that specific type net. These values are utilized by the PICKUP routine as the parameters of various random number generators used to simulate intelligence gathered. The next three rows are the preplanned EW actions that are assigned

to the specific type net. Thus when a net is identified, the disposition of the EW actions planned against the net is determined by this routine. The routines employed by EW.ROUTINE refer to these values when determining the EW functions to be employed by the EW elements. In the data set, the columns refer to a specfic type net. A one (1) in the corresponding row of that column indicates that the EW action should be initiated against that net type. A zero (0) indicates no EW action is planned for the net. For example, the one (1) in the first row of column five (5) indicates that a jamming action against net type 5. The zeros in the next two rows denote that no intercept or direction finding actions are planned for this net type. After the EW actions are read, the routine reads the sweep rates and frequency bandwidths of the jammers and terminates.

INPUT VARIABLES

none

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
CE.STRUCTURE	none	none

No block diagram is provided for this routine, however figure 7 is a sample of the input data.

```
1   3.0  15.0   180.0   180.0     300.0     180.0   0.60
 8 10   10   10   10   10  10   10   10   10   10   10   INTID(I,1)
24 30   30   30   20   20  20   20   20   20   20   20   INTID(I,2)
 0  0    0    0    0   1   0    0    0    0    0    0   JAMACT(I)
 1  1    1    0    1   0   1    1    1    1    1    1   COMACT(I)
 1  1    1    0    1   0   1    1    1    1    1    1   DFACT(I)
 2   5        15                         SWEEP RATES
 3   100      500    2000                JAMMER BANDWIDTHS IN KC
```

Figure 7: Data set NEWTHES(EWDATA): Routine EW.INITIALIZE

L. ROUTINE EW.ROUTINE

This routine is the heart of the electronic warfare module. EW.ROUTINE is called each time there is a communications attempt from the event COMMO.ATTEMPT. Initially, EW.ROUTINE calls the routine JAMLOOK to determine if the transmission passed to the EW.ROUTINE is on a net currently being jammed. If this is the case, then all other EW actions are bypassed and the EW.ROUTINE ends. However, if JAMLOOK determines that no active jammer is presently assigned to the net, EW.ROUTINE next determines whether the transmission is on a net type that is 'friendly', and if so, the net is not eligible for EW actions and the routine

terminates. If the net is eligible for EW actions, EW.ROUTINE calls the routine DF.MON to determine if a DF station is monitoring the transmission's frequency. EW.ROUTINE then determines the eligibility of the net for interception. If the net can be intercepted, then a time of interception is generated dependent upon whether the net is known or unknown. If the net type is known the time of interception will be less than the time of interception if the net is of unknown type. If the net type is known, the routine MON.PROB is called to provide a probability that the DF station is monitoring the transmission's frequency. If the transmission is monitorable, the routine RCV.SIG is called to determine if the EW station can hear the transmission. Whenever this is true, EW.ROUTINE calls the Routine PICKUP to complete the EW actions against the target net. If the transmission had been on a net type that was unknown, EW.ROUTINE would call the Routine BUS.PROB to determine if the interceptor was busy. If the interceptor was not busy, then a time of interception would be generated and compared to the length of the transmission. If the transmission was interceptable, then RCV.SIG and PICKUP are called. Upon return from the routine PICKUP, EW.ROUTINE terminates.

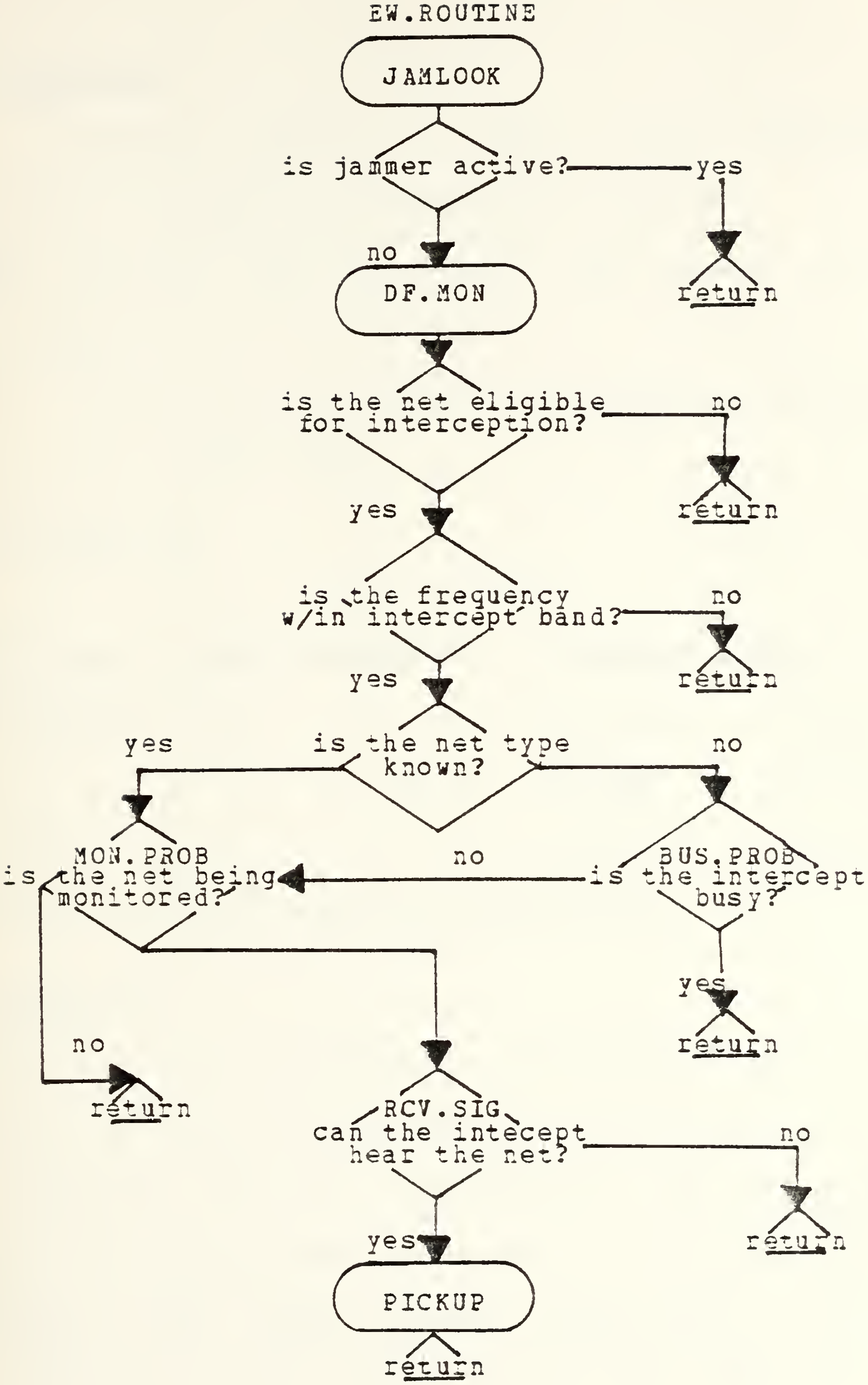


Figure 8: Block Diagram (Routine EW.ROUTINE)

INPUT VARIABLES

MSG	Pointer used to denote the transmission investigated for possible EW actions.
CALLRT	Pointer used to denote the element that is attempting to communicate.
RECRT	Pointer used to denote the receiving station of the transmission.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED	
COMMO.ATTEMPT	none	BUS.PROB	JAMLOOK
		DF.MON	RVC.SIG
		MON.PROB	PICKUP

Figure 8 is a block diagram of this routine.

M. EVENT JAM

The event JAM is scheduled in the routine each time a jammer is available and the jamming station can tune to the net's frequency prior to termination of the transmission. Initially the jam mission is assigned to an available jammer and added to the jamming mission target list. Then the event determines if the jammer is utilizing spot jamming or

barrage jamming. If the jammer is utilizing barrage jamming, the event terminates. However, if the jammer is utilizing spot jamming, then the event schedules a LOOK.THRU to determine a length for the jamming mission and the event ends with the initiation of a jamming mission.

INPUT VARIABLES

TGTFR	Pointer used to denote the frequency of the net over which a communications attempt is being made.
JAMSTA	Pointer used to denote the jamming station assigned the jamming mission.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
JAMLOOK	LOOK.THRU	none

No block diagram is provided for this event.

N. ROUTINE JAM.ASSIGN.MISSION

Routine JAM.ASSIGN.MISSION is called by the routine TACDECIDE to simulate the assignment of a jamming mission to the jamming elements. In this routine, the net type over which the transmitting station is attempting to communicate is added to the target list of the appropriate jamming element and the routine terminates.

INPUT VARIABLES

JAMSET	Pointer used to denote the jamming element to which the mission is being assigned.
OLD.TGT	Pointer used to denote the net to be added to the target list of the jamming element.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
TACDECIDE	none	none

No block diagram is provided for this routine.

O. ROUTINE JAMLOOK

The routine JAMLOOK is called by the routine EW.ROUTINE to determine if a jammer is jamming the frequency of the net over which the transmission is attempted or if the frequency is identified as a jamming target. If a jammer is available, then KJAM is set equal to one (1), denoting jamming, and the routine ends since all other EW actions are masked by the jam mission. If there is no jamming in progress, then the routine determines if the transmission is on a net that has been identified and has a jamming as the EW action planned against the net. If the net is jammable, then the routine determines if there is a jamming station

available to be assigned a jamming mission. If no jammer is available, then the routine returns to EW.ROUTINE. However, if a jammer is available the routine RCV.SIG is called to determine if the jamming element has the ability to intercept the transmission. If the jamming station can hear the transmission, then an event JAM is scheduled and the routine terminates returning the value of KJAM to EW.ROUTINE.

INPUT VARIABLES

CALLRT	Pointer used to denote the source of the transmission.
MSG	Pointer used to denote the transmission passed to JAMLOOK from EW.ROUTINE.

OUTPUT VARIABLES

KJAM	Variable used to denote the status of jamming with respect to the transmission. This variable can be set in two modes: 0 = no jamming in progress or scheduled. 1 = jamming in progress or a JAM has been scheduled.

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
EW.ROUTINE	JAM	RCV.SIG

Figure 9 is a block diagram of this routine.

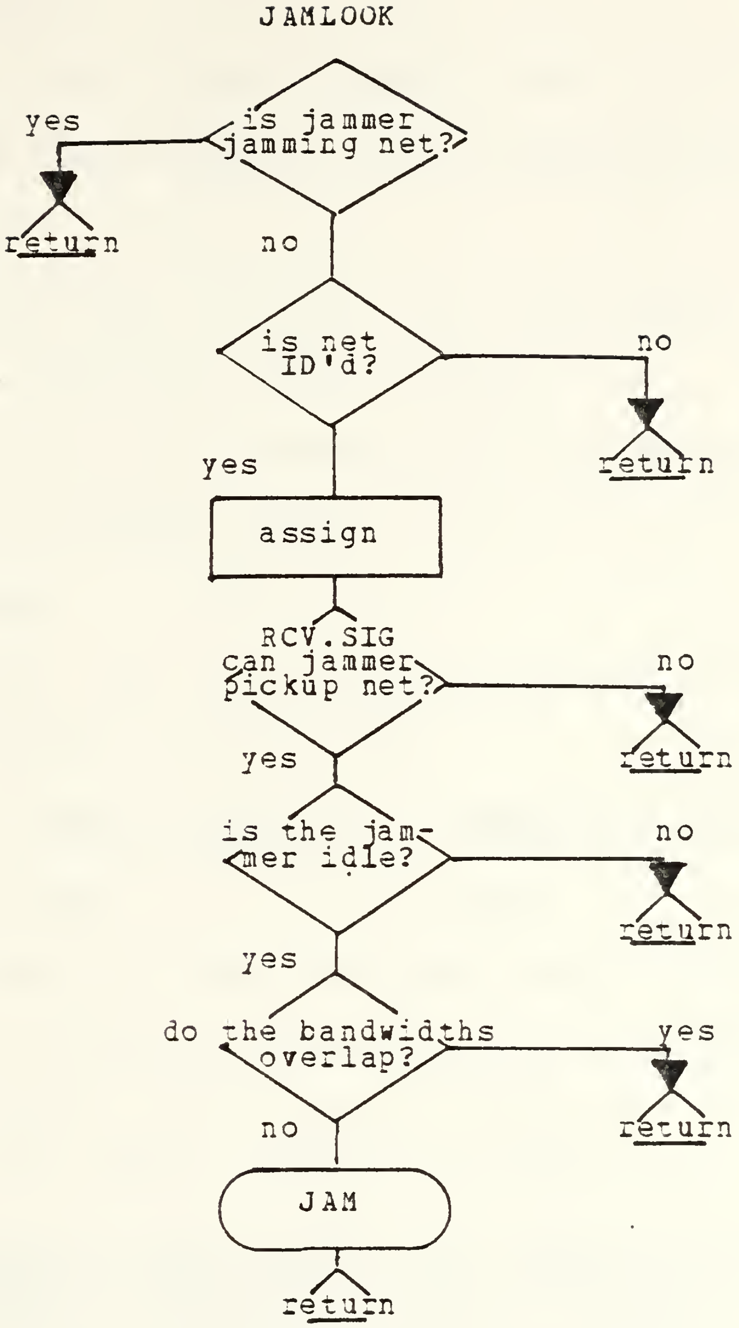


Figure 9: Block Diagram (Routine JAMLOOK)

P. ROUTINE LOB

The routine LOB is used to simulate the taking of a line of bearing from the DF station to the transmitting station.

INPUT VARIABLES

CALLRT	Pointer used to denote the transmitting station whose location is being sought.
DFSITE	Pointer used to denote the DF element taking the line of bearing (LOB).

OUTPUT VARIABLES

PHI	Pointer used to denote the value of the LOB calculated in the routine.

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
DF.SHOT	none	none

No block diagram is provided for this routine, however the equations used to calulate PHI are provided in figure 10.

THETA = ARCTAN.F((YT-YD),(XT-XD))

PHI = THETA + NORMAL.F(0.,EROR,23)

WHERE XT = CURRENT X-COORDINATE OF THE TRANSMITTING STATION.
YT = CURRENT Y-COORDINATE OF THE TRANSMITTING STATION.
XD = CURRENT X-COORDINATE OF THE DF STATION.
YD = CURRENT Y-COORDINATE OF THE DF STATION.
EROR = error factor that the DF station cannot correctly determine the exact location of the transmitting station.

Figure 10: PHI Equations (Routine LOB)

Q. EVENT LOOK.THRU

The event LOOK.THRU is schedule in the event JAM to simulate the actions of a jamming station while it is actively jamming a net. Since the no communications are possible during a jamming action, the jammer has no knowledge of the effectiveness of the jamming. Hence the jammer must stop jamming long enough to determine whether the transmitting station is still attempting to communicate. Initially, LOOK.THRU determines if the jammer has exceeded the jamming time, then the event shuts the jammer down and terminates, however if the jamming time is not exceeded, the event checks the target list to determine if there are jamming targets available. A target is considered available if the net has been identified and the net has jamming as the EW action planned against it. If there is a target available event JAM is scheduled. If no target is available the jammer is shutdown and the event terminates.

INPUT VARIABLES

JAMSTA	Pointer used to denote the jamming station being checked.

OUTPUT VARIABLES

none

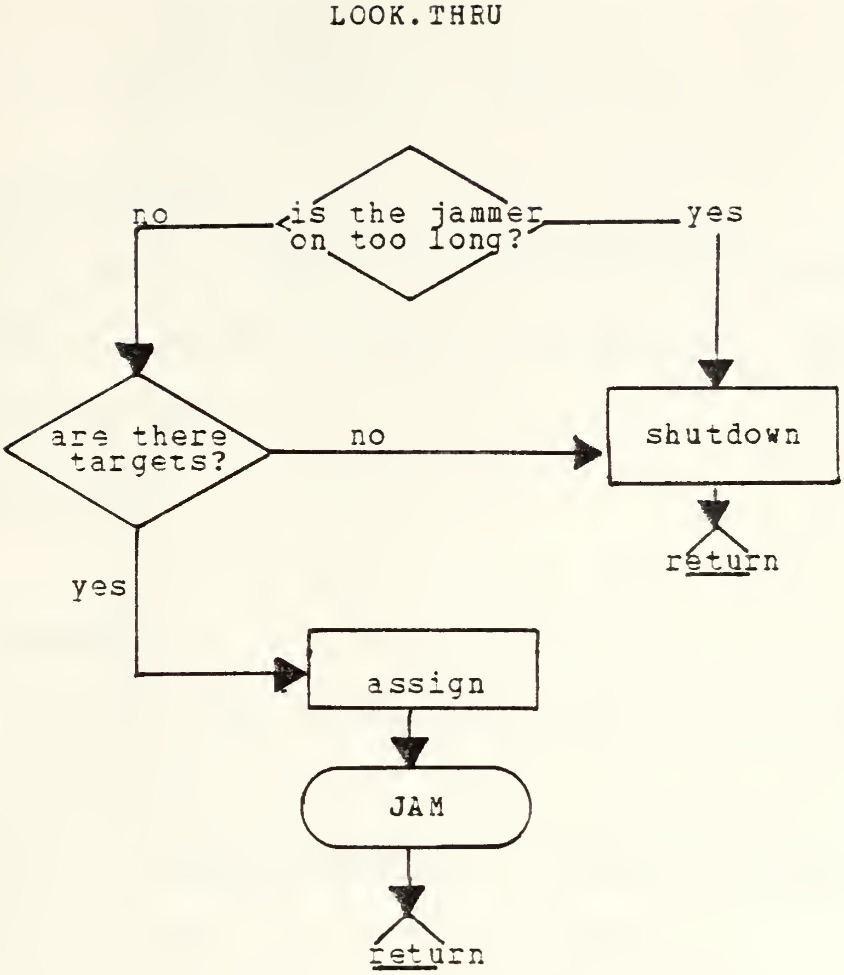


Figure 11: Block Diagram (Event LOOK.THRU)

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
JAM	LOOK.THRU	none

Figure 11 is a block diagram for this event.

R. ROUTINE MON.PROB

This routine is called by EW.ROUTINE to provide that routine with a value to compare a probability that the net can be intercepted.

INPUT VARIABLES

none

OUTPUT VARIABLES

PR.MON	Pointer used to denote the value of the monitoring probability.

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
EW.ROUTINE	none	none

No block diagram is provided for this routine.

S. ROUTINE NEW.COMINT.REPORT

Routine NEW.COMINT.REPORT is called by the routine PICKUP to simulate the actions of the parent analysis station of the EW platoon. Initially, the routine determines whether the net type is on the master target list of the the analysis station. If the transmitting net is

intercepted for the first time, then the net is added to the master target list of the analysis station and the net becomes an EW.TGT. Then the new EW targets, as well as the transmissions that were determined to be old targets, have their number of intercepts identified compared to the INTID value assigned in the routine EW.INITIALIZE. These comparisons are utilized to determine whether the net is identified or not. If the net is identified for the first time, the routine TACDECIDE is called to determine the appropriate jamming action to be initiated against the net. After NEW.COMINT.REPORT determines whether the net type is known or unknown the routine passes this information to the Routine PICKUP and terminates.

INPUT VARIABLES

INTSITE	Pointer used to denote the intercept station that has intercepted the transmission.
EWTGT	Pointer used to define the transmission as a specific EW target.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
PICKUP	none	TACDECIDE

Figure 12 is a block diagram for this routine.

NEW.COMINT.REPORT

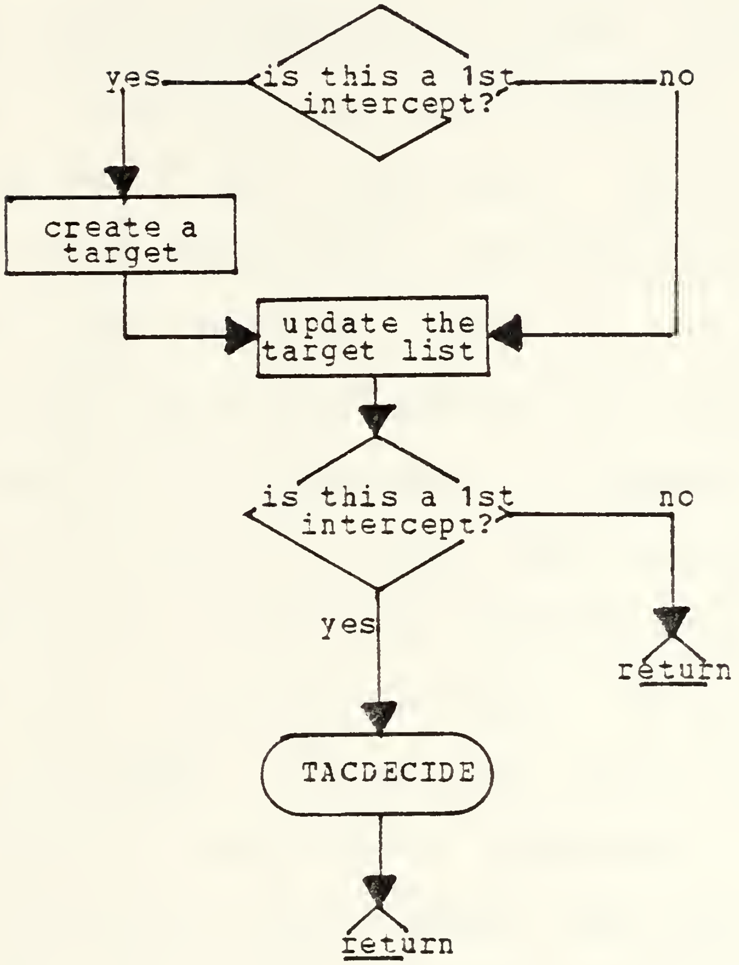


Figure 12: Block Diagram (Routine NEW.ASSIGN.MISSION)

T. ROUTINE PICKUP

The routine PICKUP is called by the routine EW.ROUTINE to simulate the intercept and analysis functions of electronic warfare. Initially, PICKUP determines whether the net type of the transmission is known or unknown. If the net type is unknown, the routine creates an EW target and adds the net to the target list. The routine then transfers to an analysis section that simulates attempts to gather information concerning the net. The fraction determined by the time of interception of the transmission and time length of the transmission is compared to a cutoff value. If the fraction is greater than the cutoff value, then enough of the transmissions was intercepted to gather some information concerning the net. This information increments the number of times this net is intercepted. When the number of intercepts is sufficient, the net is considered identified and the routine NEW.COMINT.REPORT is called to add the net to the master target list. If, however, the fraction was less than the cutoff value, then the transmission was too short to provide any information, and the routine would terminate.

If the net type of the transmission was initially known, then the PICKUP routine determines if the net is cleared for direction finding actions. If the net is not cleared for DF actions, then the routine transfer to the analysis section described in the previous paragraph occurs. If the net is cleared for DF actions, then PICKUP determines if the DF stations are idle or busy. If the DF stations are busy, analysis is again performed and the routine terminates. However, if the DF stations are idle, then the routine simulates the assignement of a DF mission by scheduling a COMMO.ATTEMPT to assign the mission and calls the routine DFCALL to assign the mission.

INPUT VARIABLES

MSG	Pointer used to denote the transmission intercepted.
CALLRT	Pointer used to denote the transmitting station being intercepted.
INTCRT	Pointer used to denote the intercept station that intercepted the transision.
TOI	Pointer used to denote the time of interception of the transmission.

OUTPUT VARIABLES

none

PICKUP

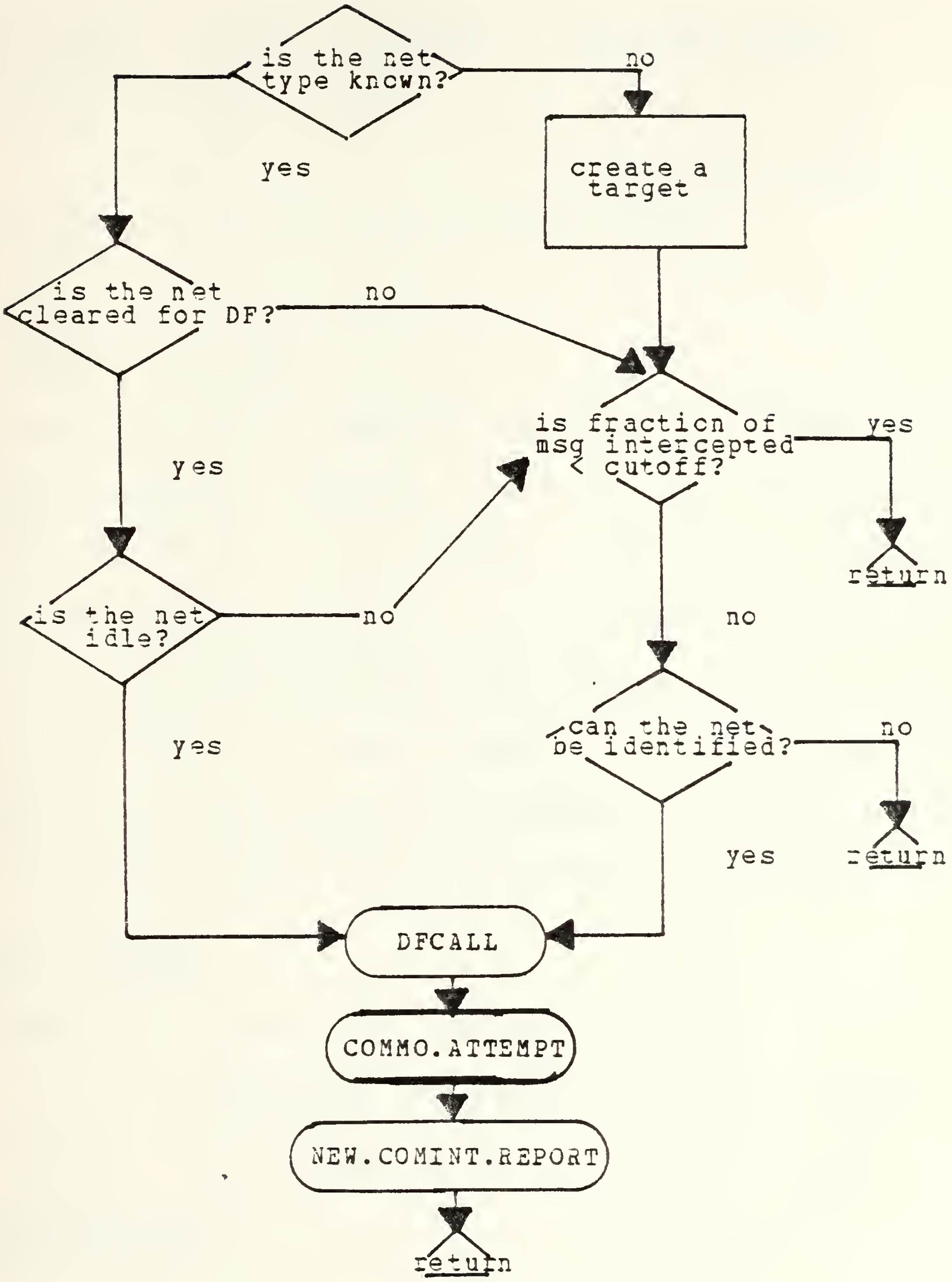


Figure 13: Block Diagram (Routine PICKUP)

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
EW.ROUTINE	COMMO.ATTEMPT	DFCALL NEW.COMINT.REPORT

Figure 13 is a block diagram of this routine.

U. ROUTINE TACDECIDE

Routine TACDECIDE simulates the decision process of the analysis position's commander when determining whether a net should be jammed or not jammed. The routine initially determines the disposition of the EW actions planned against the net. If jamming actions are planned against the net then the routine JAM.ASSIGN.MISSION is called to assign the jamming mission and the routine terminates. If the net type has no jamming actions planned, the routine terminates.

INPUT VARIABLES

OLD.TGT	Pointer used to denote the net type to be assigned or not assigned jamming actions.
PROC.SITE	Pointer used to denote the EW element.

OUTPUT VARIABLES

none

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
DF.REPORT	none	JAM.ASSIGN.MISSION
NEW.COMINT.REPORT		

No block diagram is provided for this routine.

V. ROUTINE TRIG

This routine is used to simulate the calculation of the location of a transmitting station after sufficient lines of bearing had been taken.

INPUT VARIABLES

X1, Y1, X2, Y2	Values used to represent the x and y-coordinates of the transmitting station and the DF station, respectively.
PHI	Value used to represent the line of bearing determined in the routine LOB.
MU	Value used to denote the number of lines of bearing calculate in the routine DF.FIX.

OUTPUT VARIABLES

X.DF, Y.DF	The calulated position of the transmitting station.

CALLED FROM	EVENTS SCHEDULED	ROUTINES CALLED
DF.FIX	none	none

No block diagram is provided for this routine.

APPENDIX B

THE PARAMETRIC T-TEST

This appendix outlines the statistical procedure for testing if the means of two populations are equal when the variance of the populations is unknown but assumed equal.

The statistic to be used is the T-statistic and is defined by the following formula:

$$T=(X1-X2)/(sp \times 1/N1 + 1/N2)$$

In this formula X1 equals the mean of the first sample and X2 equals the mean of the second sample. SP equals the pooled standard deviation of the two samples. N1 is the number of observations in the first sample and N2 is the number of observations in the second sample. The null hypothesis to be tested is U1=U2 where U1 is the actual mean of the first population and U2 is the actual mean of the second population. The alternate hypothesis is that U1>U2. At the desired level of significance the actual value of the T-statistic can be found in a T-statistic table.

The null hypothesis is rejected if T of 1-alpha with degree of freedom of (N1+N2)-2 is less than the test T-statistic computed from the data.

APPENDIX C

THE NON-PARAMETRIC U-TEST

The nonparametric U-Test is used as an alternative to the two sample t-statistic. In this test, the assumption that the two populations sampled have normal distributions is not made. Instead, the null hypothesis is that we are sampling identical continuous populations and the alternative hypothesis is that the two populations have unequal means.

In the test involving different remaining military worths, the U-test procedure would be as follows: there are two sets of data representing remaining military worths for 10 runs with no jamming initiated and 10 runs with jamming conducted against the blue forces artillery forward observers.

Jamming	38.2	37.2	37.2	36.3	38.9	36.6	34.1	38.6	38.0	36.4
No Jamming	36.7	37.7	43.2	40.5	37.7	38.5	37.2	38.5	37.7	38.2

First, arrange the data in increasing order as if the two samples were one sample. Assign a rank to each piece of data. If there are ties, assign to each of the tied

observations the mean of the ranks which they jointly occupy. In this example, there are several ties. To illustrate the procedure for ties we observe that the percentage 37.2 occurs 3 times and would occupy ranks 6,7, and 8. The mean of these ranks is 7 therefore each of the 37.2 percentages would be assigned the rank of 7. The jamming sample occupies ranks 5,7,10,10,10,13.5,15.5,15.5,19, and 20. The no jamming sample occupies ranks 1,2,3,4,7,7,12,13.5,17, and 18. W1 is defined as the sum of the ranks of the no jamming sample and W2 is defined as the sum of the ranks of the jamming sample.

$W1=84.5$

$W2=125.5$

$U1=W1-n1x(n1+1)/2$

$U2=W2-n2x(n2+1)/2$

In this calculation, n1 and n2 represent the number of observations in each sample. Under the null hypothesis, the means and the variances of U1 and U2 are:

$E(U1)=E(U2)=n1xn2/2$ and

$Var(U1)=Var(U2)=n1xn2x(n1+n2+1)/12$

Using the data in this example, the test is as follows:

1. Ho: $u1=u2$

2. H1: $u1<u2$

3. Critical region:

$z<-z(.05)=-1.645$ where $z=(U1-E(U1))/ Var(U1)$

4. Computations

$U1=84.5-(10x11)/2 = 29.5$

$E(U1)=n1xn1/2=10x10/2 = 50$

$Var(U1)=10x10x21/12 = 175$

$z = 29.5-50/ \sqrt{175} = -1.55$

Since $z=-1.55$ is greater than $-z(.05)$, we do not reject the null hypothesis and must conclude that at the level of significance of .05 the means of the two samples are equal. Further analysis at various levels of significance shows that at levels of significance greater than or equal to .10, the null hypothesis will be rejected.

LIST OF REFERENCES

1. Hartman, J. K., *Parametric Terrain and Line of Sight Modelling in the STAR Combat Model*, Naval Postgraduate School, Technical Report, NPS55-79-018, August 1979.

2. Hartman, J. K., *Ground Movement Modelling in the STAR Combat Model*, Naval Postgraduate School, Technical Report NPS55-80-021, Monterey, CA, May, 1980.

3. Wallace, W. S. and Hagewood, E. G., *Simulation of Tactical Alternative Responses (STAR)*, M.S. Thesis, Naval Postgraduate School, Monterey, CA, December 1978.

4. Starner, S. G., *A Two-sided Field Artillery Stochastic Simulation*, M.S. Thesis, Naval Postgraduate School, Monterey, CA, March 1980.

5. Kramer, J. S., *Simulation of Dynamic Tactical Route Selection with Application in the STAR Model*, M.S. Thesis, Naval Postgraduate School, Monterey, CA, March 1979.

6. Broussard, G. J., *A Dynamic Study of Factors Impacting on the Tank Commanders Selection Process*, M.S. Thesis, Naval Postgraduate School, Monterey, CA, March, 1979.

7. Haislip, W. A., *Communications/Electronic Warfare Modules for Simulation of Tactical Alternative Responses (STAR) Combat Model*, M.S. Thesis, Naval Postgraduate School, Monterey, CA, June,1980.

8. Olson, P. A. Jr., *Parametric Simulation of Tactical Single Channel Frequency Modulated Communications*, M.S. Thesis, Naval Postgraduate School, Monterey, CA, September 1980.

9. FM 100-33, *Information Text: Electronic Warfare Operations* Deparment of the Army, United States Army Signal School, Fort Gordon, Ga., August, 1979, pp. 1-4 to 1-5.

10. FM 32-30, *Electronic Warfare, Tactics of Defense*, Deparment of the Army, August, 1976, p. 1.

11. Ibid., p. 1-2.

12. FM 100-33, *Information Text: Electronic Warfare Operations* Deparment of the Army, United States Army Signal School, Fort Gordon, Ga., August, 1979, pp. 1-4 to 1-5.

BIBLIOGRAPHY

Department of the Army, FM *11-50 Combat Communications Within the Division*, March 1977.

Department of the Army, *TC 30-12-1 Communications Jamming An Element of Combat Power*, October 1977.

Department of the Army, *TC 32-05-2PT Electronic Counter-Countermeasures* (ECCM) *Procedures for the Communicator*, June, 1977.

Freund, J. E. and Walpole, R. E., *Mathematical Statistics*, 3rd. ed., Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1980.

Dixon, W. J. and Massey, F. J. Jr., *Introduction to Statistical Analysis*, 3rd ed., McGraw-Hill Book Company, 1969.

Kelleher, E. P. Jr., *Simulation of the Tactical Employment of Field Artillery*. M.S. Thesis, Naval Postgraduate School, Monterey, Ca., December, 1977.

Maressa, F. M. and Rozman, J. T. Jr., *An Investigation of a Light Air Defense System in the Infantry Division*, M.S. Thesis, Naval Postgraduate School, Monterey, Ca, March, 1982.

Parry, S.H. and Kelleher, E.P., *The Tactical Parameters and Input Requirements for the Ground Components of the STAR Combat Model*, Naval Postgraduate School Technical Report NPS 55-80-021 Monterey, May, 1980.

Stockfisch, J.A., *Models, Data, and War: A Critique of the Study of Conventional Forces*, US Air Force Project RAND Report R-1526-pr, March, 1975.

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